Measuring Optical and Thermal Properties of High Temperature Receivers

Johannes Pernpeintner, Thomas Fend

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DLR

Part I:

Thermal properties of receivers for

SOLAR TOWER TECHNOLOGY

→ Thomas Fend

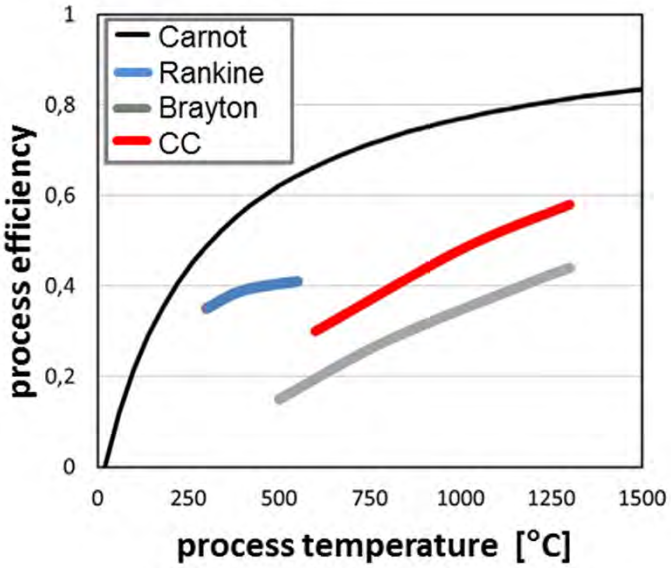
Part II:

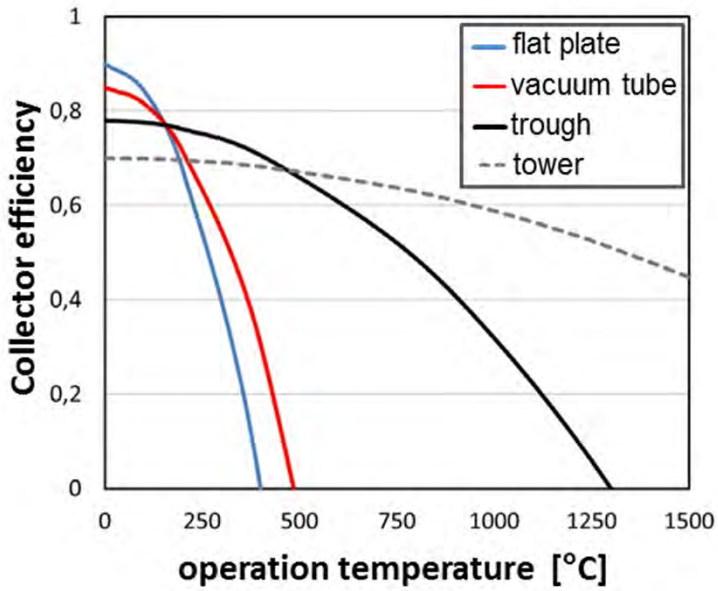
Optical and thermal properties of tube receivers for

PARABOLIC TROUGH TECHNOLOGY

→ Johannes Pernpeitner

Why Solar Tower Technology?





- Efficiency limited by thermal engine
- Higher temperatures – higher efficiencies

- Higher losses at higher temperatures
- Higher concentration ratio

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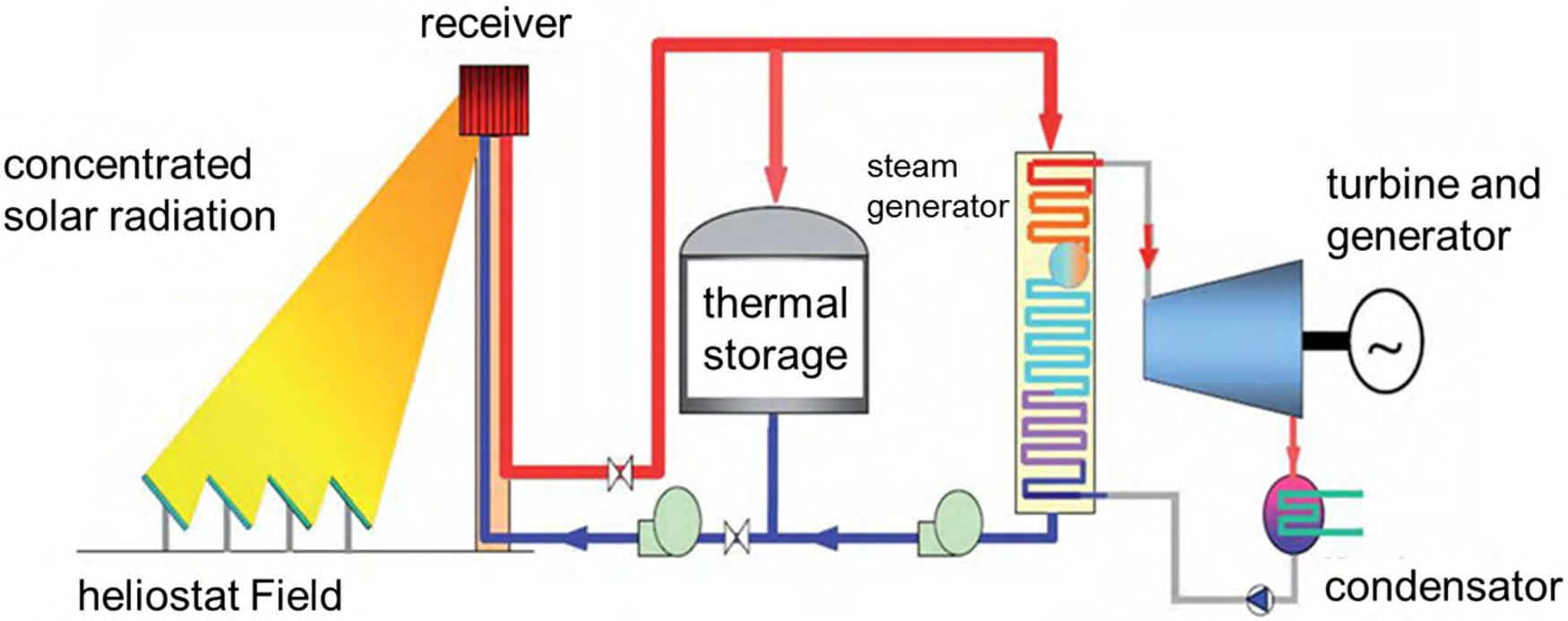
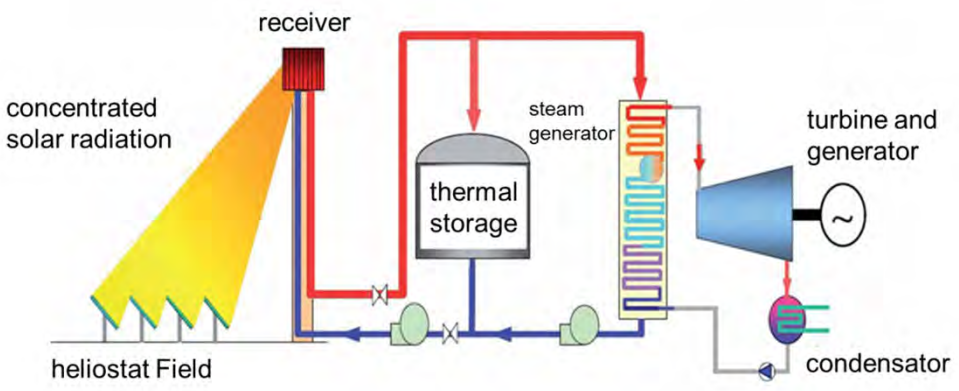
Solar Tower Technology: Example



Receivers for Solar Tower Technology

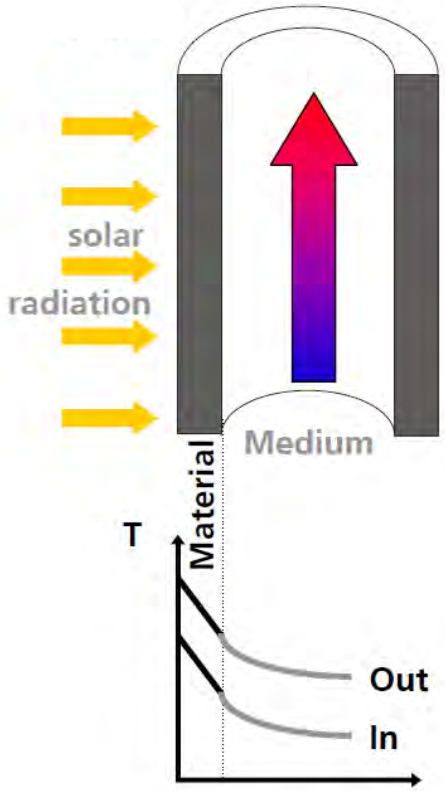


- volumetric receivers
- tube receivers
- direct medium receivers
- …

Tube Receivers

- absorption on outer tube surface
- transport of heat through tube wall to a medium
- **media:** liquid salt, liquid metal, water, air

- thermal resistance
- non homogeneous heating
- tube surface temperature is higher than medium temperature



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Solar Two

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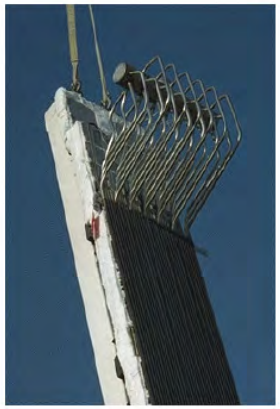

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Tube Receivers

Gemasolar

- absorption on outer tube surface
- transport of heat through tube wall to a medium
- **media:** liquid salt, liquid metal, water, air

Source: torresolenergy

- thermal resistance
- non homogeneous heating
- tube surface temperature is higher than medium temperature

Tube Receivers

PS10/PS20

- absorption on outer tube surface
- transport of heat through tube wall to a medium
- **media:** liquid salt, liquid metal, water, air

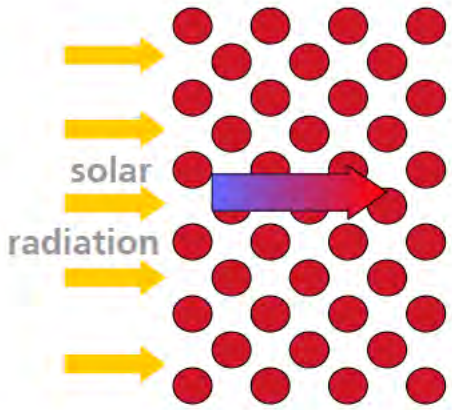
Source: desertec UK

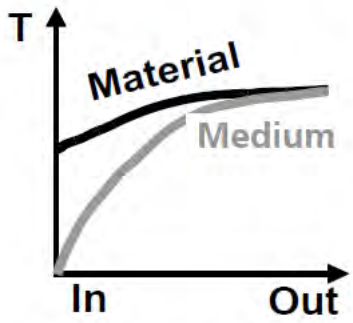
- thermal resistance
- non homogeneous heating
- tube surface temperature is higher than medium temperature

Volumetric Receivers

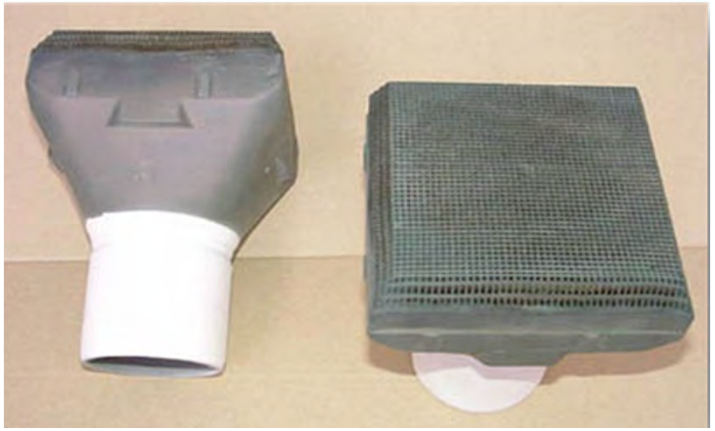
- Radiation absorbed in the porous volume of the receiver
- Front temperature lower than medium temperature

- **Medium:** air, pressurized air





Volumetric Receivers



- Radiation absorbed in the porous volume of the receiver
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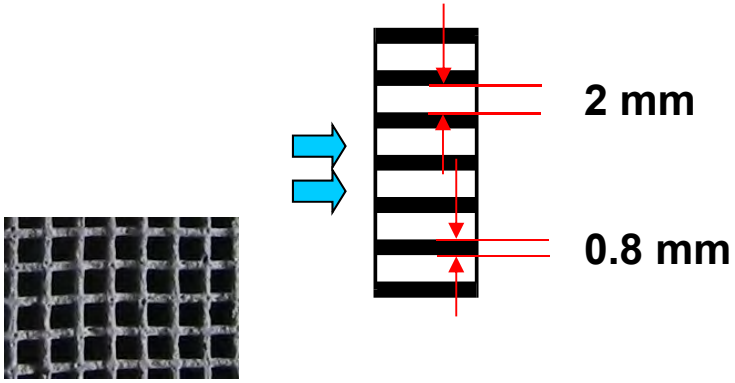

Volumetric Receivers

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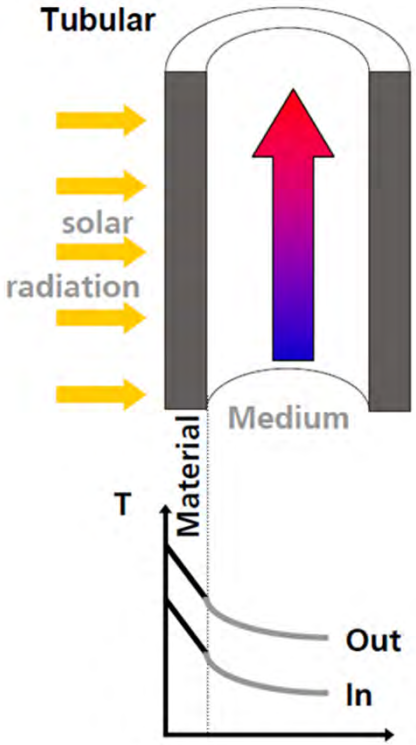
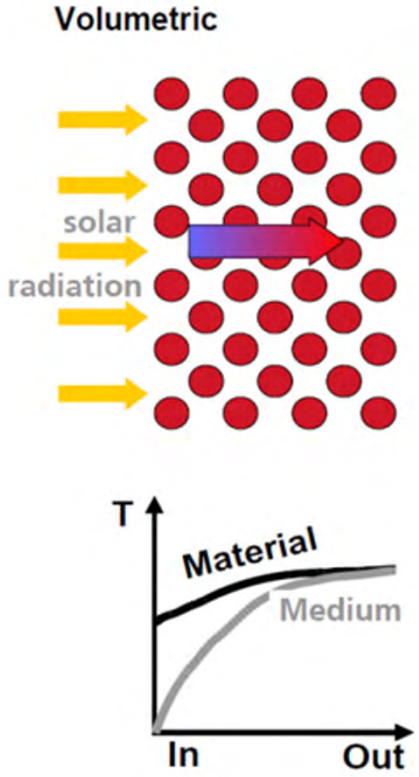
Solar Tower Jülich

Tower: 60m
2153 Heliostats (8.2 m²)
22.7 m² receiver aperture
1 h thermal storage
500°C/ 30 bar
1.5 MW_{el} turbine

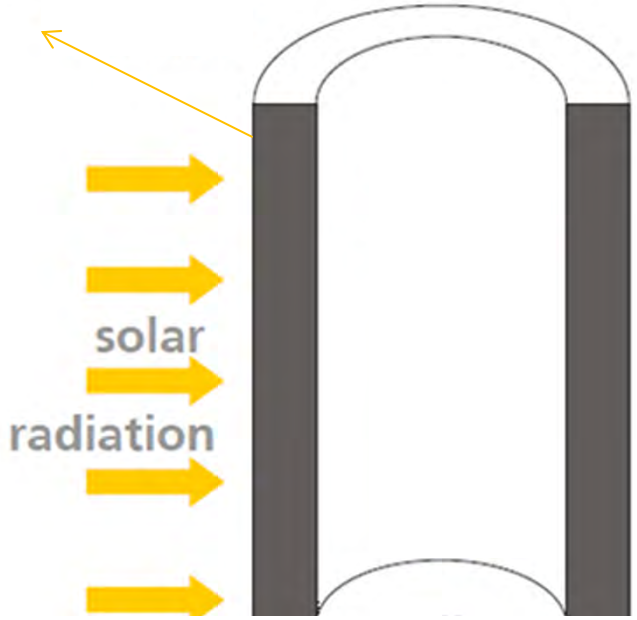
SOLARTURM JÜLICH

Thermal Performance Prediction



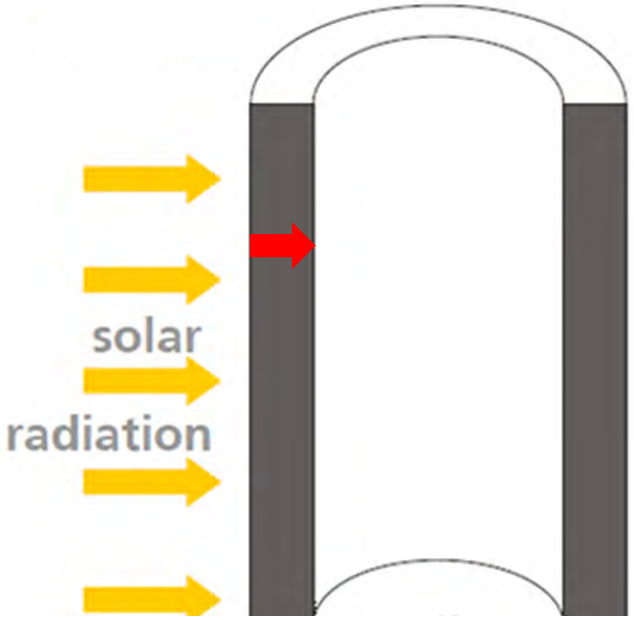


Thermal Performance Prediction



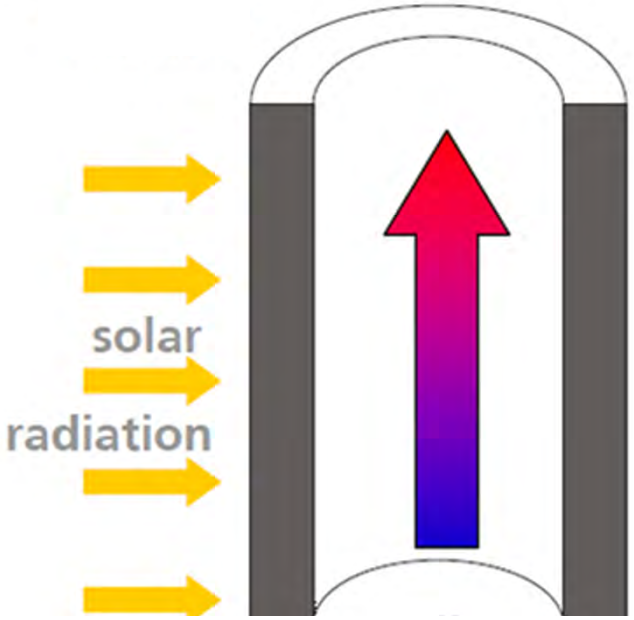
- Absorption

Thermal Performance Prediction



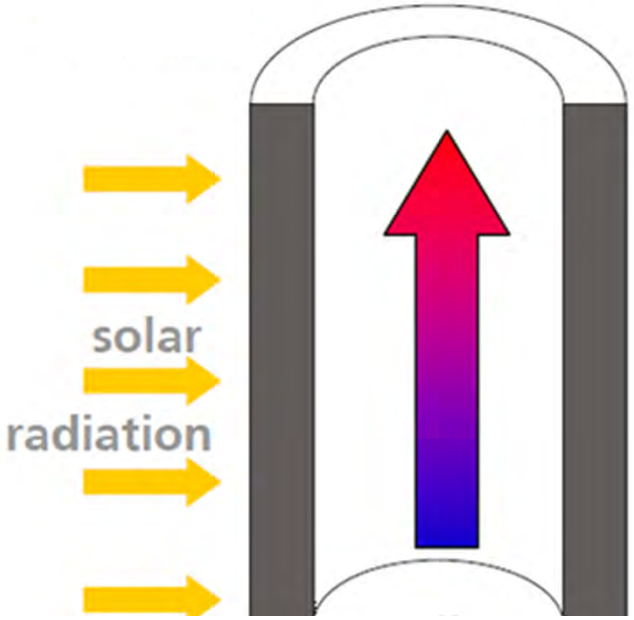
- Absorption
- Conductive resistance in tube wall

Thermal Performance Prediction



- Absorption
- Conductive resistance in tube wall
- Convective resistance

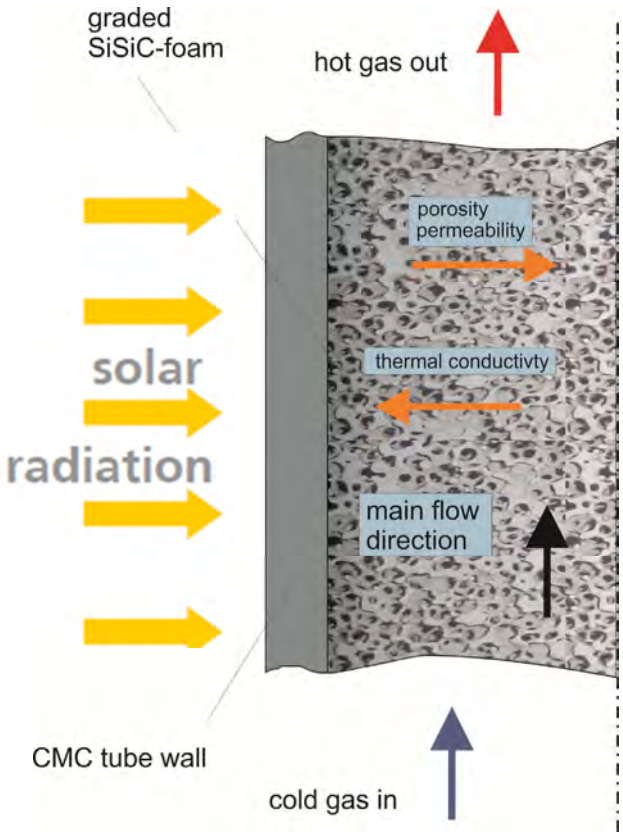
Thermal Performance Prediction



- Absorption
- **Conductive resistance in tube wall**
- **Convective resistance**

→ tables
→ standard techniques
→ optimization of process by geometry and thermal properties of the employed material

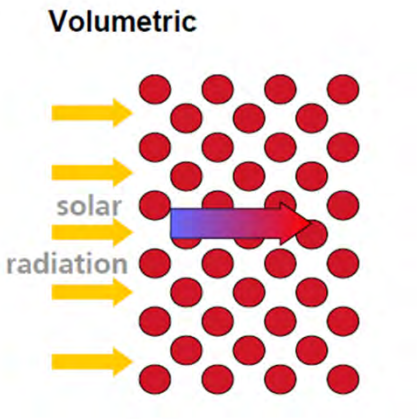
Thermal Performance Prediction: Heat Transfer Enhancing Concepts

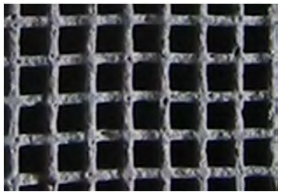


- Increased heat transfer surface
- Enhanced heat transfer by gradation in radial direction
- Thermal properties of porous material needed
- Proposed in Korean/Swiss/German project ***CMC4CSP***

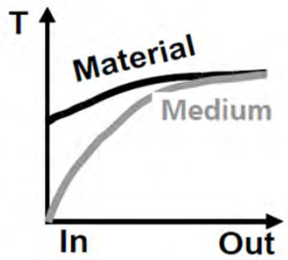
Thermal Performance Prediction: Volumetric Receiver

- Conductive resistance and
- Convective resistance in ***porous volume***





→ Advanced experimental techniques necessary if non uniform pore geometries are used



Thermal Performance Prediction

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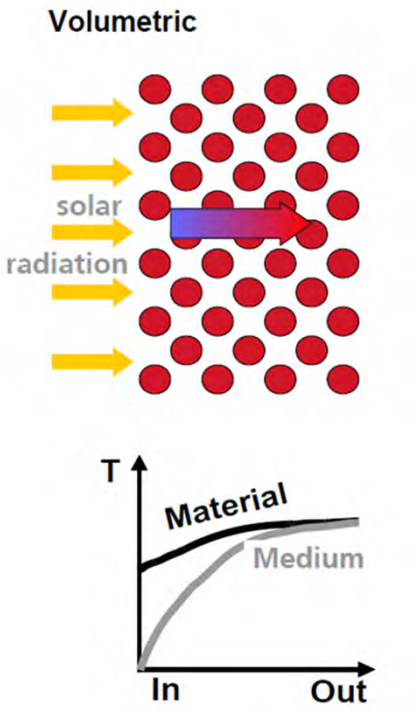

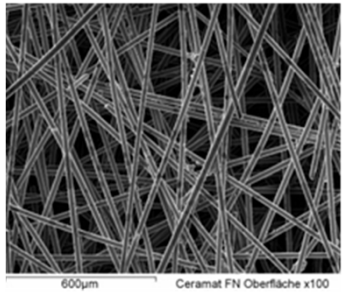

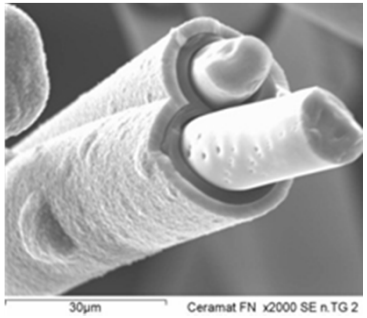

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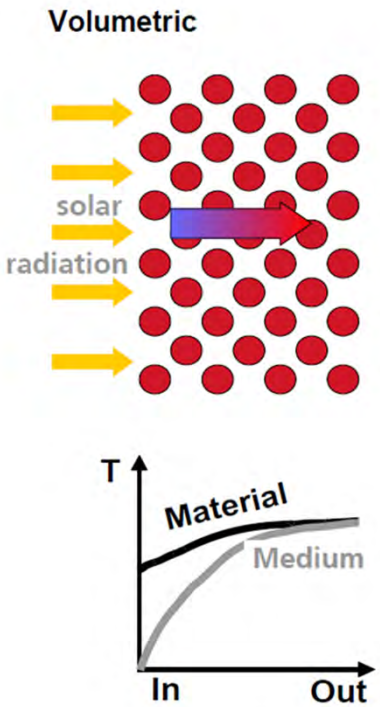
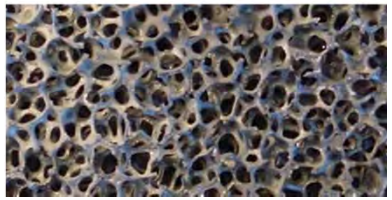
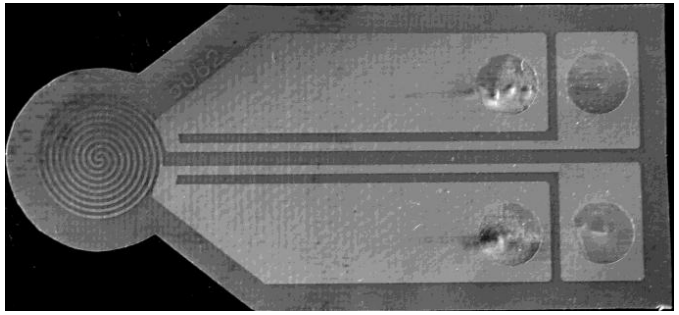
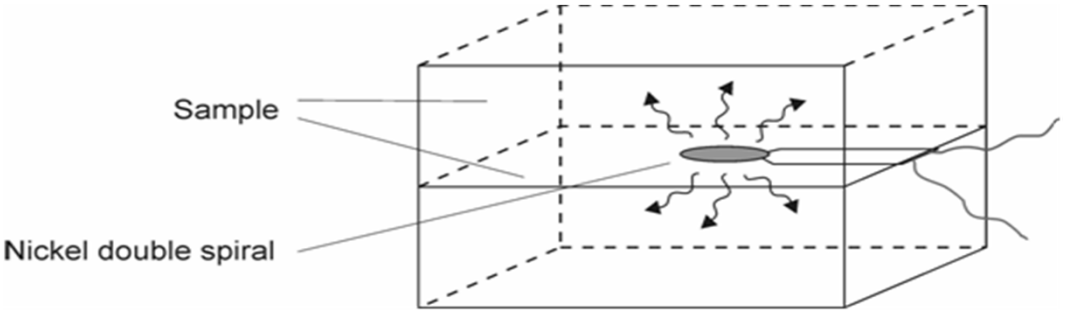




Thermal Conductivity of Porous Materials

- Transient Plane Source Technique
  + Measurement of characteristic volumes
  + mesurement yields
    - effective thermal conductivity
    - effective thermal diffusivity
    - heat capacity





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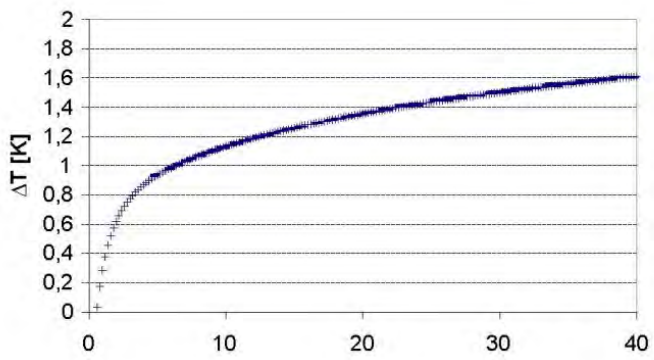
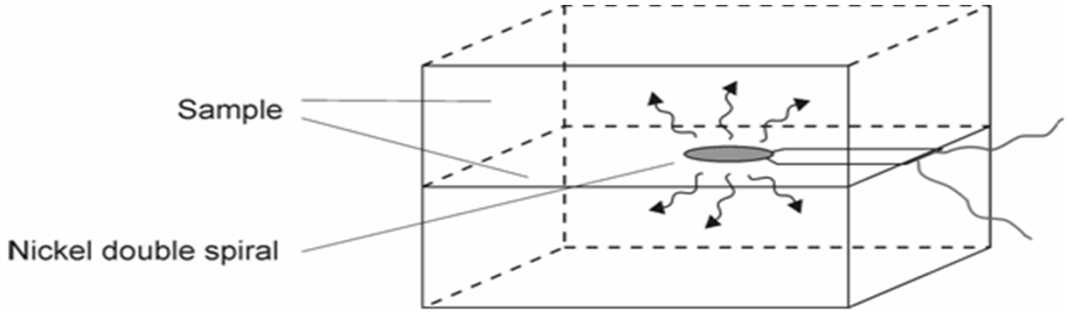
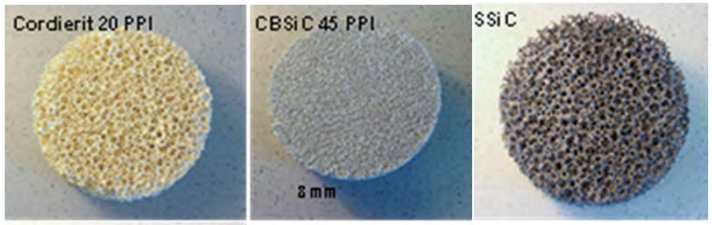
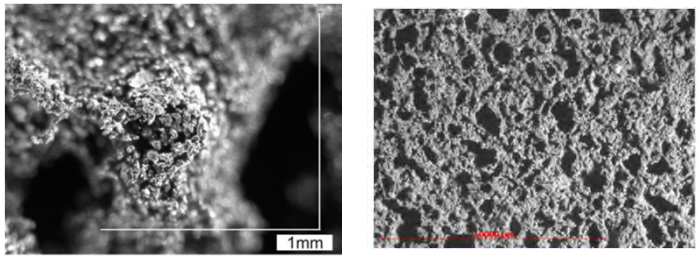
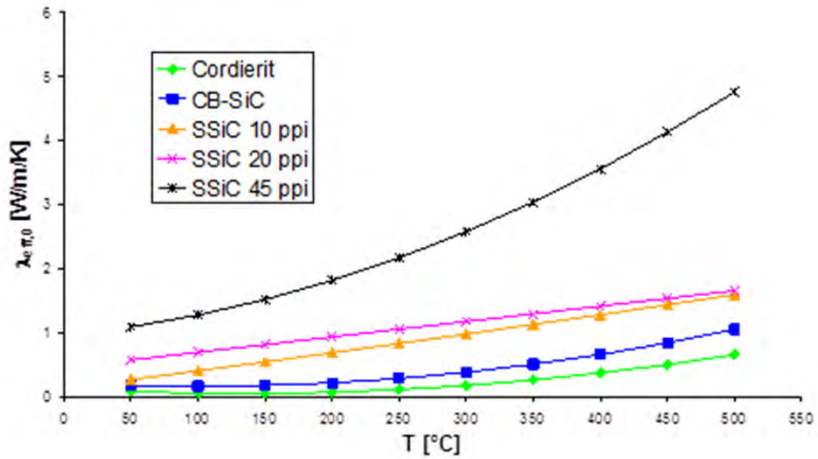


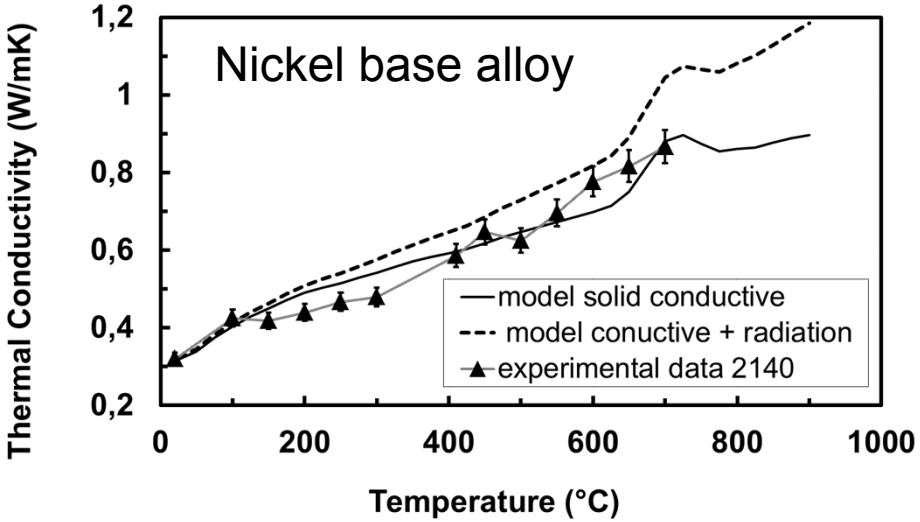


Effective Thermal Conductivity of Porous Materials: Metal Foams









Convective Resistance in Porous Volume

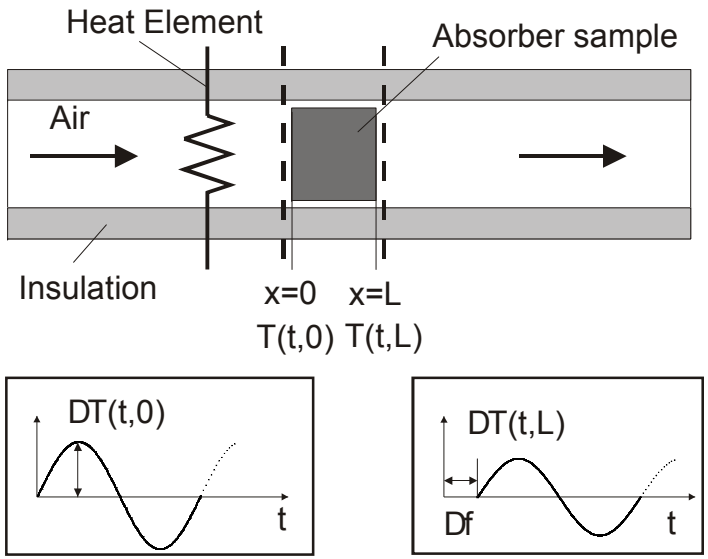
- two phase approach in continuum model
- Additional term in energy equations of solid and fluid phase

$$\lambda_{eff}\nabla^2 T_S - \alpha A_v (T_S - T_F) = 0$$

$$\dot{m} C_P \frac{dT_F}{dx} - \alpha A_v (T_S - T_F) = 0$$

αA_v: volumetric convective heat transfer coefficient

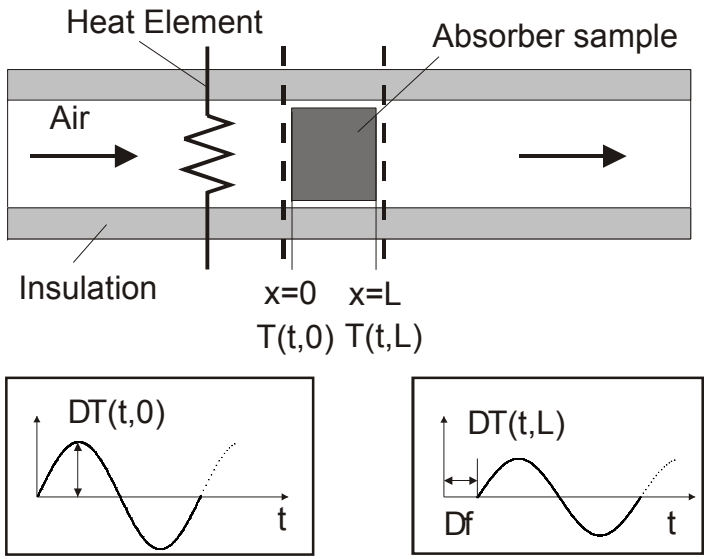
Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient αAv: *AAF-method* [1]

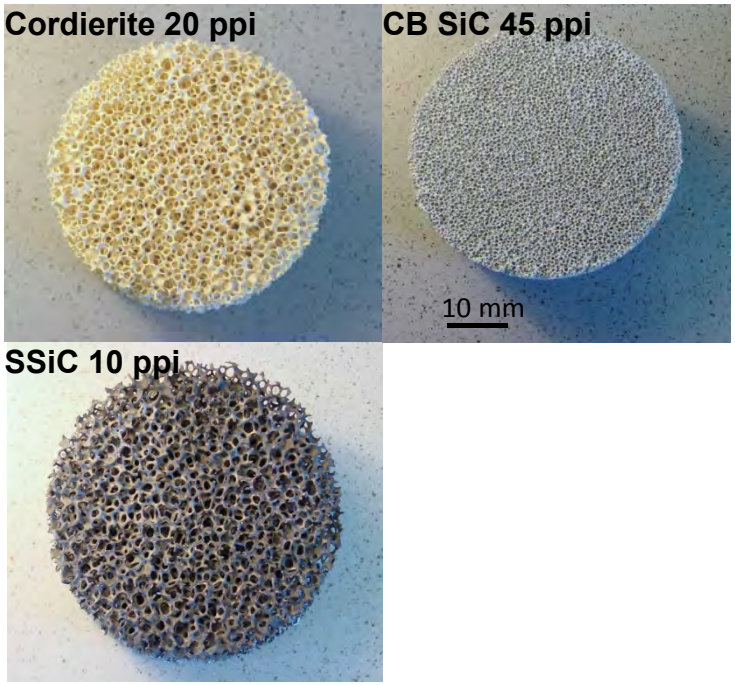


- Air flow with alternating temperature profile induced
- Porous sample causes phase shift and amplitude attenuation
- αAv determined

1.) Alternating Air flow method after Younis and Viskanta

Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient αAv: *AAF-method*





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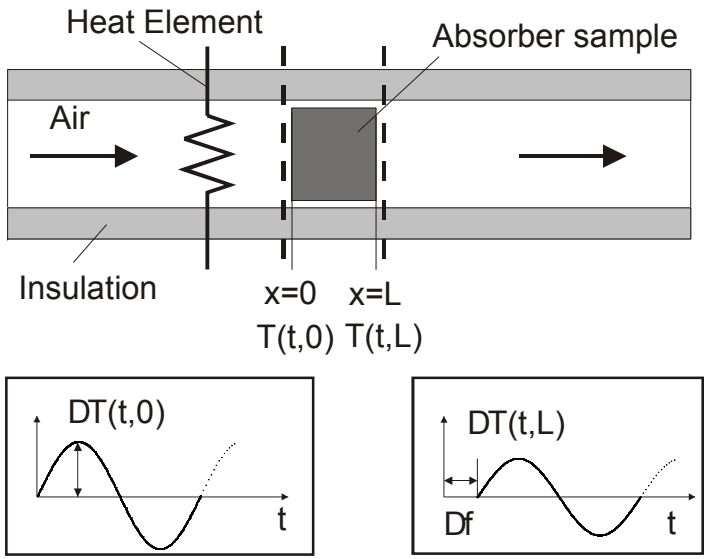

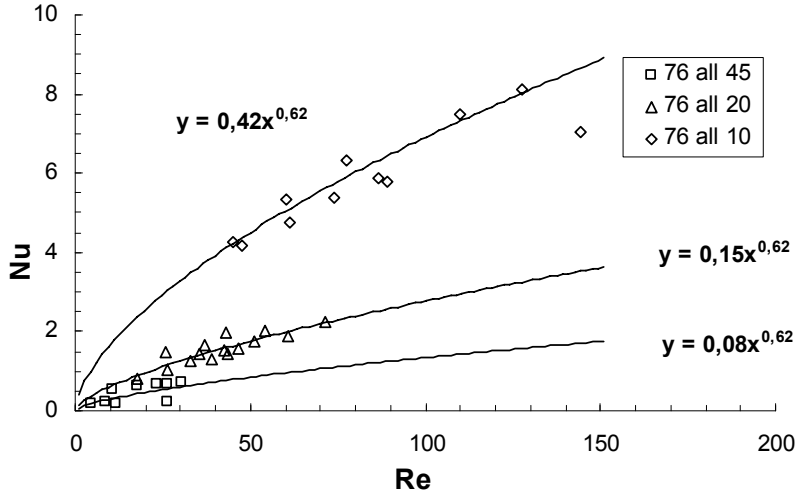

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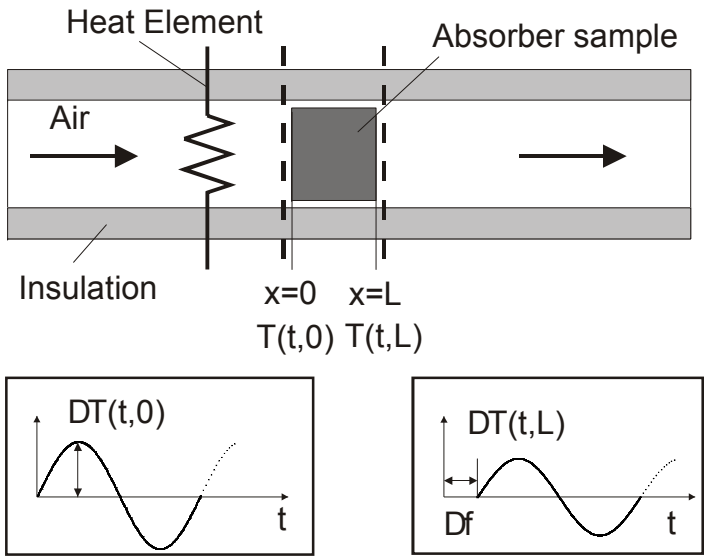
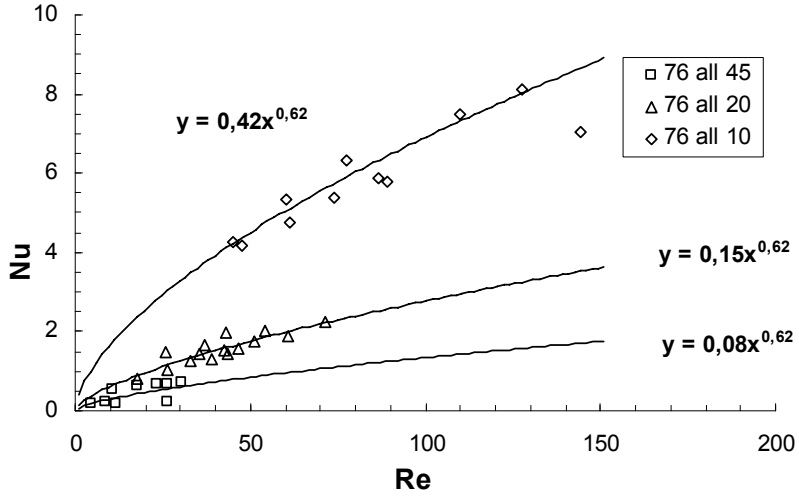
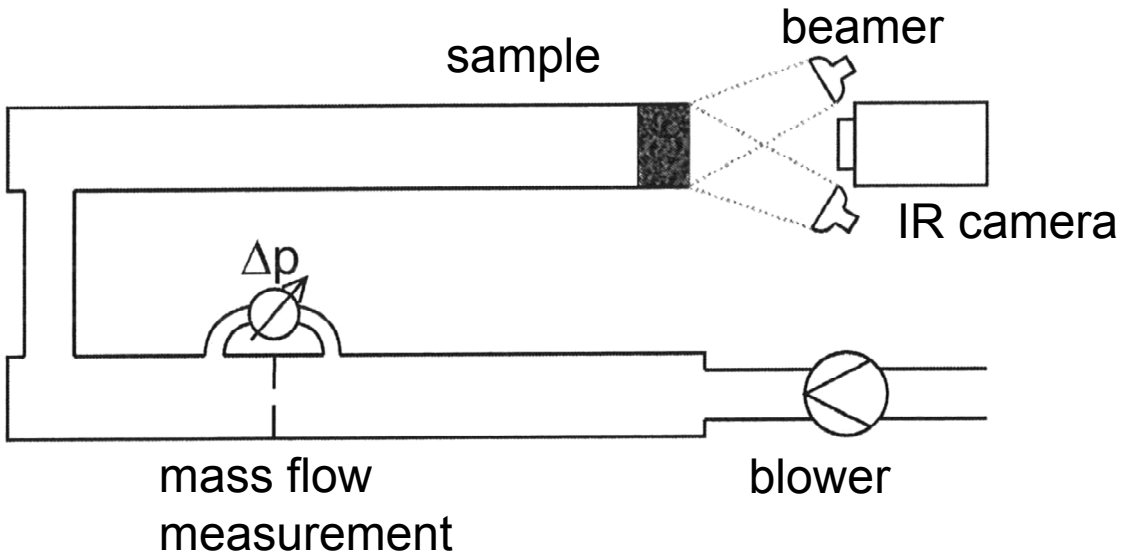




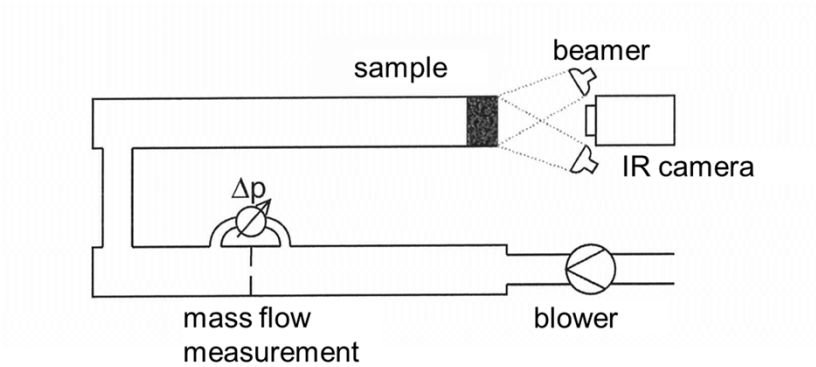
$$Nu = 4.8 \cdot n_{PPI}^{-1.1} \cdot \mathrm{Re}^{0.62}$$

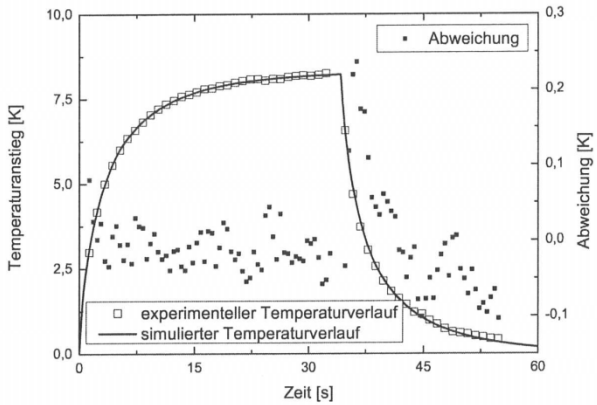
Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient αAv: *AlAv-method*[1]



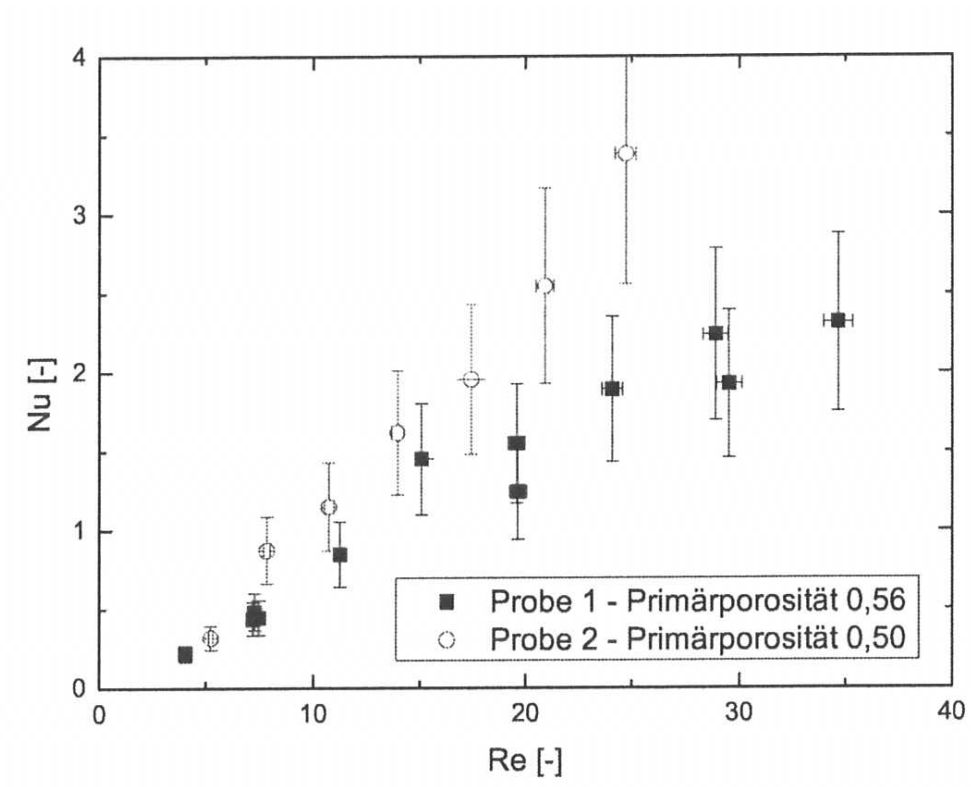
1.) AlphaAv-method after Brendelberger et al.

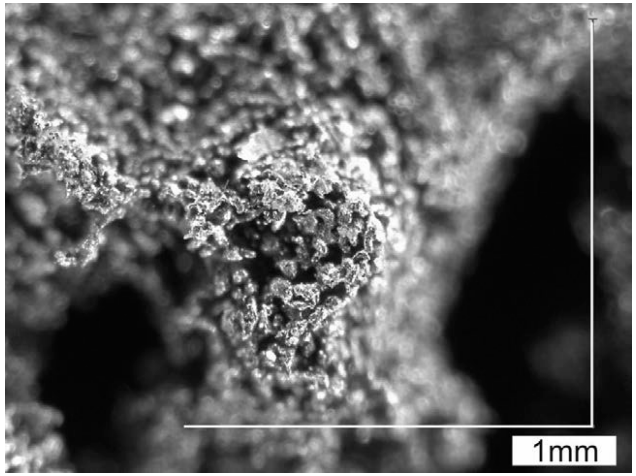
Experimental Set-Up for Volumetric Convective Heat Transfer Coefficient αAv: *AlAv-method*

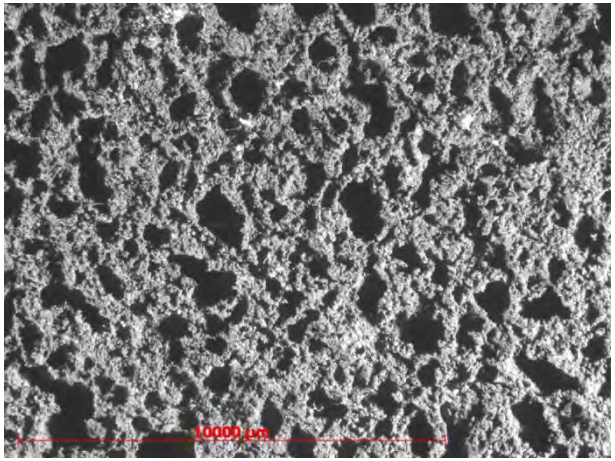




The *AlAv-method: Results on Metal Foams*







Conclusions

- For the prediction of the thermal performance of high temperature components characteristic quantities are needed
- Transient plane Source Technique for thermal conductivity measurement
- AAF and AlAV method for volumetric convective heat transfer properties